

## TITLE OF THE INVENTION

MAGNETORESISTANCE EFFECT ELEMENT, MAGNETIC HEAD, MAGNETIC HEAD ASSEMBLY, MAGNETIC STORAGE SYSTEM

## FIELD OF THE INVENTION

The present invention relates to a magnetoresistance effect device, a magnetic head, a magnetic head assembly, and a magnetic recording/reproducing system. More precisely, it relates to a magnetoresistance effect device, a magnetic head, a magnetic head assembly, and a magnetic recording/reproducing system, in which is used a giant magnetoresistance effect element having high sensitivity and high reliability.

## BACKGROUND OF THE INVENTION

The recent tendency in the art is toward small-sized, large-capacity magnetic recording media, for which there are increasing great expectations of high-power MR heads (magnetoresistance effect heads). For the MR film which is the basic constituent element in those MR heads, widely noticed is a spin valve film having a multi-layered magnetic film with a sandwich structure of magnetic layer/nonmagnetic layer/magnetic layer, in which one magnetic layer is pinned for its magnetization owing to the magnetic coupling bias applied thereto (this layer may be referred to as a "pinned magnetic layer" or "pinned layer") while the other magnetic

layer is reversed for its magnetization owing to the applied magnetic field (this layer may be referred to as a "free magnetic layer" or "free layer"). The spin valve film of that type produces a giant magnetoresistance effect (GMR) through the relative angle change in the magnetization direction between those two magnetic layers.

As other types of MR films, known are an anisotropic magnetoresistance effect film (AMR film) made of an NiFe alloy or the like, an artificial lattice film, etc. Though smaller than that in an artificial lattice film, the MR ratio in a spin valve film is at least 4 % and is much larger than that in an AMR film. A spin valve film can saturate its magnetization even in a low magnetic field, and is therefore suitable to MR heads. MR heads incorporating such a spin valve film receive much expectations for their practical applications. Specifically, for increasing the recording density in magnetic recording on magnetic discs and the like, high-sensitivity GMR heads (giant magnetoresistance effect heads) are indispensable.

Early GMR heads incorporate, in its GMR device, a spin valve film that comprises a free layer, a nonmagnetic spacer layer, a pinned magnetic layer and an antiferromagnetic layer. In those, the increase in the sensitivity of the film is indispensable for increasing the recording density through reduction in the recording track width. However, if the free

layer is thinned so as to increase the sensitivity of the film for that purpose, the stray magnetic field from the pinned magnetic layer will shift the bias point. In that case, it is often difficult to effectively correct the thus-shifted operating point by the current magnetic field.

On the other hand, a so-called laminated pinned ferromagnetic layer (hereinafter referred to as "SyAF", or "Synthetic AF") has been proposed (USP No. 5,465,185), which comprises two ferromagnetic layers as antiferromagnetically coupled via an antiferromagnetically coupling layer existing therebetween. In principle, the antiferromagnetically-coupled, pinned layer of that type would produce very small stray magnetic field, thereby readily ensuring the operating point.

One case of a spin valve film with SyAF is referred to, in which one of the two ferromagnetic layers adjacent to the nonmagnetic spacer layer is a ferromagnetic layer A while the other adjacent to the antiferromagnetic layer is a ferromagnetic layer B and in which the ferromagnetic layer A and the ferromagnetic layer B have the same magnetic thickness, thickness  $\times$  saturation magnetization. In that case, the stray magnetic fields from the layer A and layer B cancel each other so that there is substantially no stray magnetic field generated by the pinned layer. As a result, the pinned layer of that type is no more susceptible to a magnetic field and